

# BI107 CHAP 9

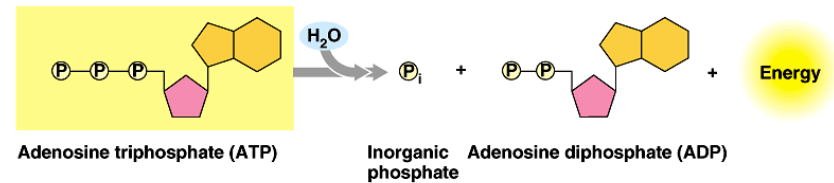
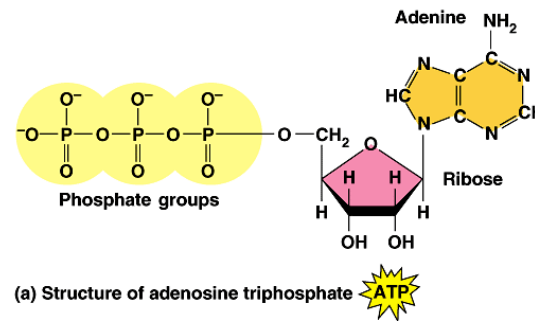
## Principles of Energy Harvesting

# Harvesting of Energy

- Cellular respiration & fermentation are catabolic, energy yielding pathways
- Organic compounds store energy in the arrangement of atoms
- Complex organic molecules rich in chemical potential energy are broken down in metabolic pathways called catabolic pathways to waste products having much less energy
- Some of energy released is used to do work & rest dissipated as heat
- Fermentation is the partial degradation of glucose occurring without oxygen
- Cellular respiration is the complete breakdown of glucose with oxygen consumed as a reactant where most of the breakdown occurs in mitochondria
- Carbohydrates, fats & proteins can be used as the energy source but usually discuss breakdown of glucose
- Breakdown is exergonic – products of the process store less energy than reactants free energy change is  $-686\text{kcal}$  per mole of glucose

# Harvesting of Energy cont.

- Catabolism of glucose linked to formation of ATP
- Cells recycle ATP – the central player in bioenergetics
- The triphosphate tail of ATP is like a loaded spring due to close packing of 3 negative charges which makes the tail unstable & becomes more stable by losing terminal phosphate

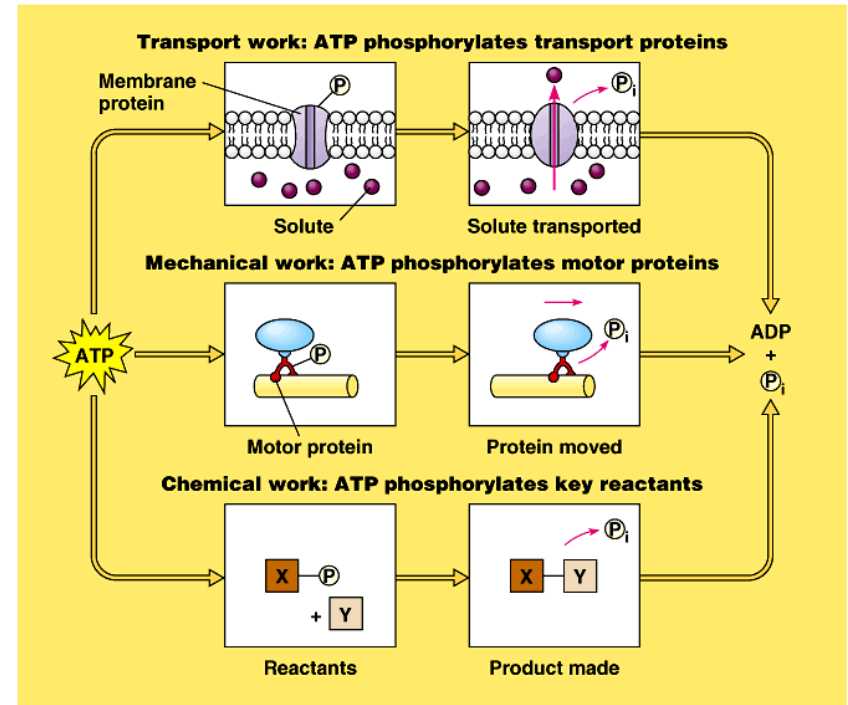


(b) Hydrolysis of ATP

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# Harvesting of Energy cont.

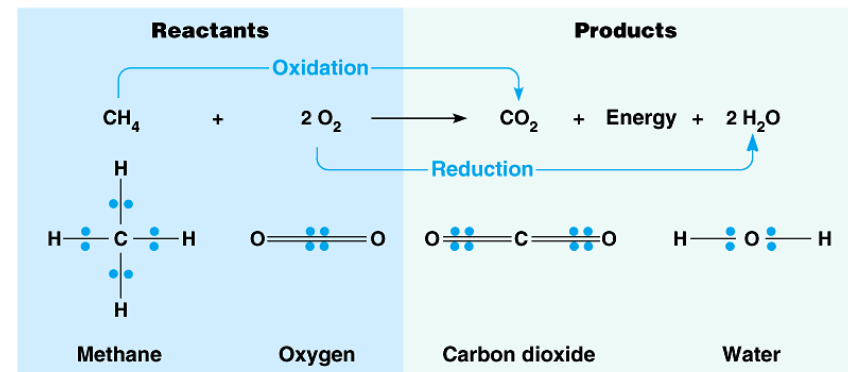
- Terminal phosphate usually transferred to other molecules which are said to be 'phosphorylated'
- Phosphorylation primes a molecule to undergo a change that performs work & the molecule loses the phosphate group in the process of doing work
- working muscle recycles ATP at 10 million/sec



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# Harvesting of Energy cont.

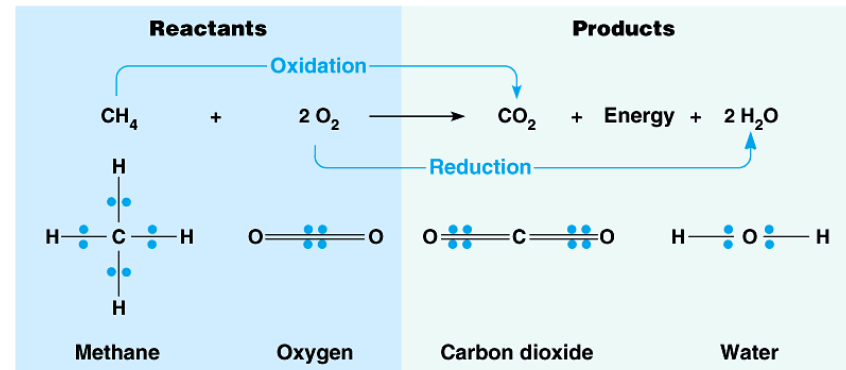
- To understand how cellular respiration regenerates ATP  
1<sup>st</sup> must understand oxidation – reduction reactions
- Catabolic pathways of cellular respiration yield energy because electrons are transferred during the chemical reactions & relocation of electrons releases energy stored in the food molecules & the released energy is used to synthesize ATP



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# Harvesting of Energy cont.

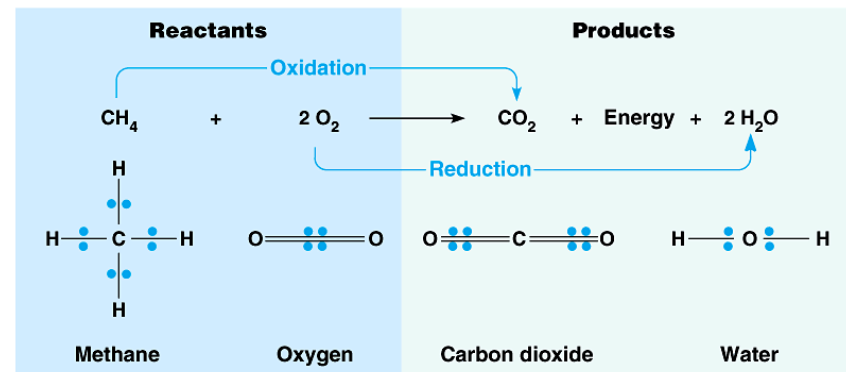
- In many chemical reactions electrons are transferred from 1 reactant to another
- Electron transfers called oxidation – reduction reactions or redox reactions where loss of electrons from a substance called oxidation & addition or gain of electrons called reduction have a donor & an acceptor so oxidation – reduction go together



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# Harvesting of Energy cont.

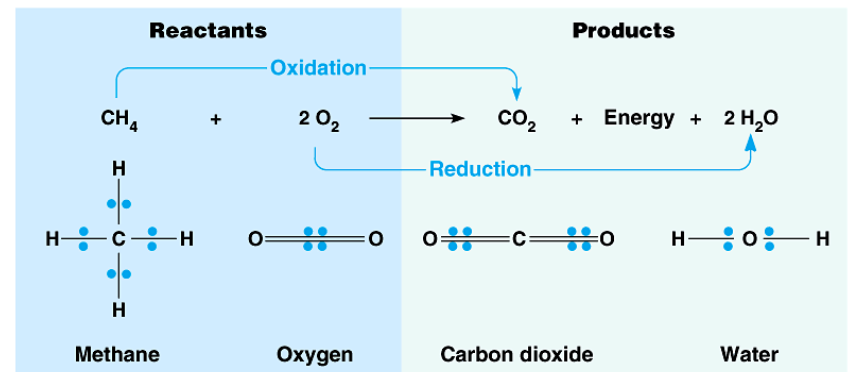
- Electron donor is the reducing agent & electron acceptor is the oxidizing agent
- Electron donor gets oxidized & electron acceptor gets reduced
- Redox reactions can involve change in the degree of sharing of electrons or actual transfer of electrons



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# Harvesting of Energy cont.

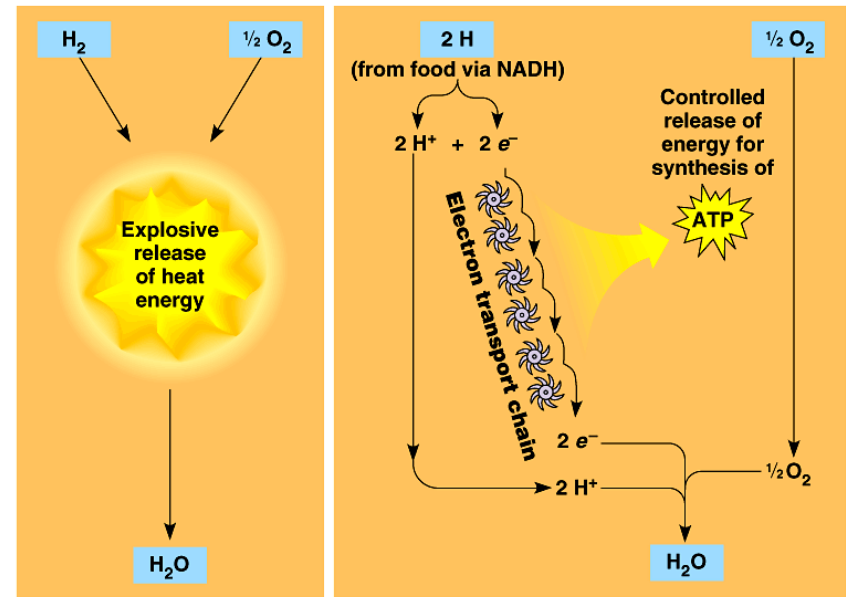
- Can go from equal sharing to unequal sharing – methane + oxygen  $\rightarrow$  carbon dioxide + water oxygen is very electronegative so it is one of most potent oxidizing agents
- An electron loses potential energy when it shifts from a less electronegative atom (weaker pull on electrons) to more electronegative atom (stronger pull on electrons)
- Redox reaction that relocates electrons closer to oxygen releases chemical energy that can be put to work



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# Harvesting of Energy cont.

- Electrons 'fall' from organic molecules to oxygen during cellular respiration
- Glucose + oxygen yields carbon dioxide + water where hydrogen is transferred from glucose to water but as important electrons change as hydrogen is transferred to oxygen releasing energy which is used to make ATP



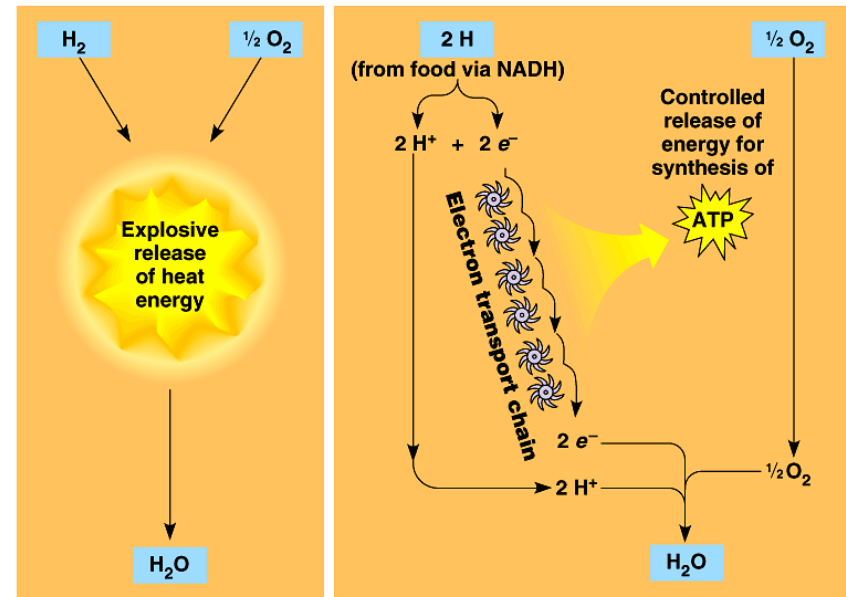
(a) Uncontrolled reaction

(b) Cellular respiration

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# Harvesting of Energy cont.

- Main energy foods, carbohydrates & fats, are reservoirs of electrons associated with hydrogen ions & only the activation energy holds back flood of electrons to lower energy state
- Can burn glucose in air by igniting it & get release of 686 kcal/mol but energy released is not useful for doing work



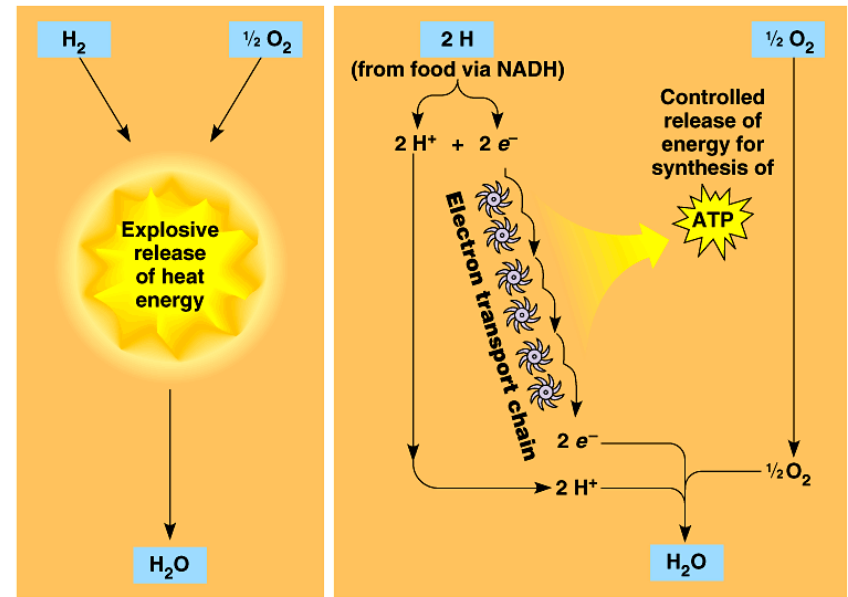
(a) Uncontrolled reaction

(b) Cellular respiration

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# Harvesting of Energy cont.

- Need controlled release of energy so it can be used to do work
- Body temperature is not high enough to ignite food molecules but enzymes lower the activation energy barrier & glucose can be oxidized slowly



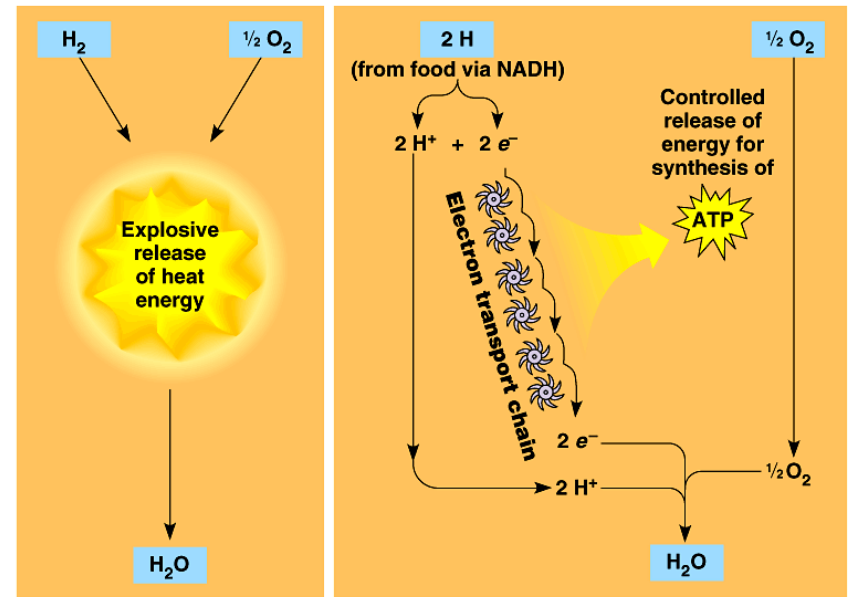
(a) Uncontrolled reaction

(b) Cellular respiration

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# Harvesting of Energy cont.

- 'fall' of electrons during cellular respiration is stepwise via  $\text{NAD}^+$  & electron transport chain
- Glucose & other organic fuels are broken down gradually in series of steps each catalyzed by an enzyme



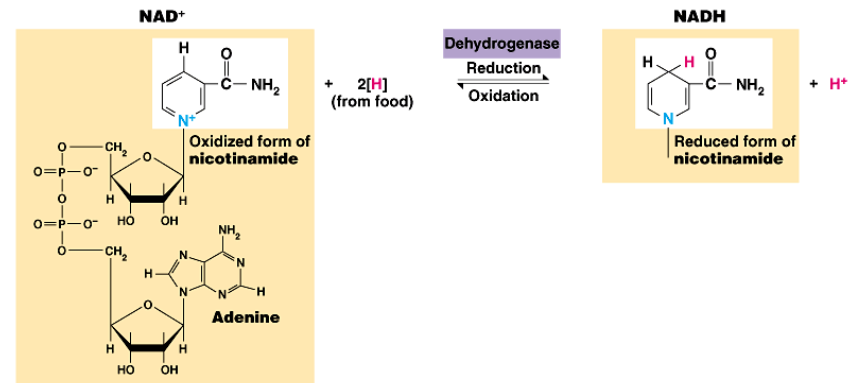
(a) Uncontrolled reaction

(b) Cellular respiration

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# Harvesting of Energy cont.

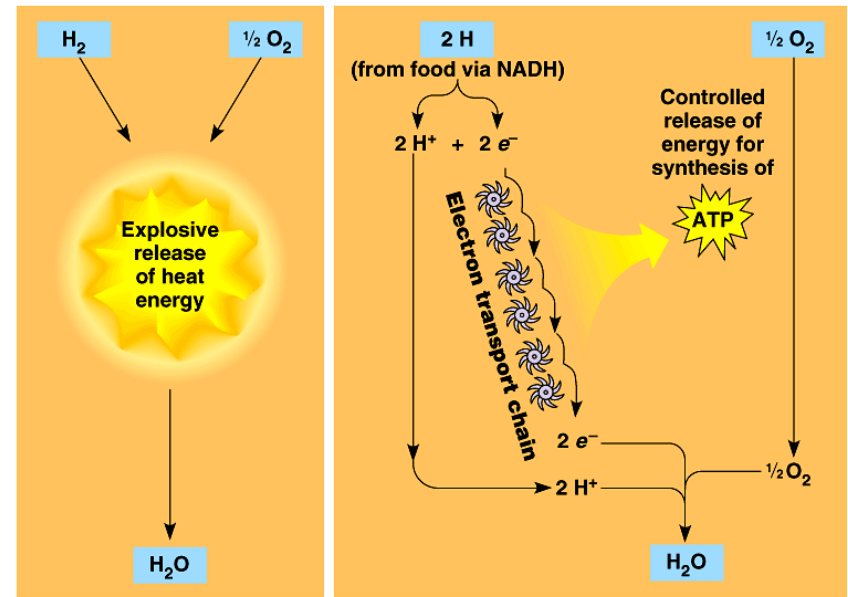
- At key steps hydrogen atoms are removed from glucose & passed, not directly to oxygen, but to a coenzyme called NAD<sup>+</sup> which functions as an oxidizing agent in cellular respiration
- Enzymes called dehydrogenases remove a pair of hydrogen atoms (2 electrons & 2 protons – nuclei of hydrogen atoms) from the substrate & delivers 2 electrons & 1 proton to the coenzyme NAD<sup>+</sup> & other proton is released as hydrogen ion



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# Harvesting of Energy cont.

- $\text{NAD}^+$  neutralized by adding 2 electrons & 1 hydrogen ion (other  $\text{H}^+$  goes into solution)
- Electrons lose very little potential energy when passed from food to  $\text{NAD}^+$  forming  $\text{NADH}$  which is stored energy which is tapped to make ATP when electrons complete the 'fall' from  $\text{NADH}$  to oxygen



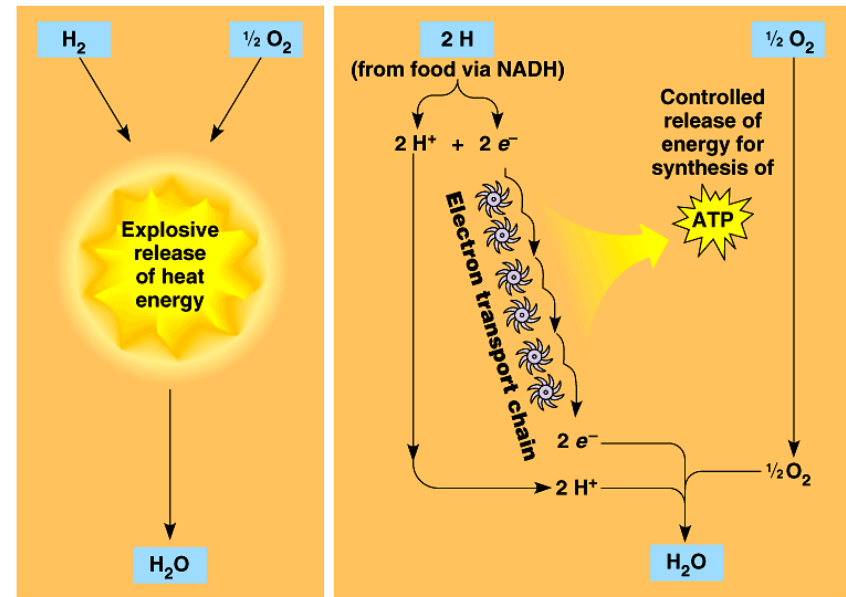
(a) Uncontrolled reaction

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# Harvesting of Energy cont.

- Cellular respiration brings hydrogen and oxygen together to form water under controlled conditions
- Hydrogen gas & oxygen gas form water with explosive release of energy but in cellular respiration hydrogen ions come from organic molecules not hydrogen gas



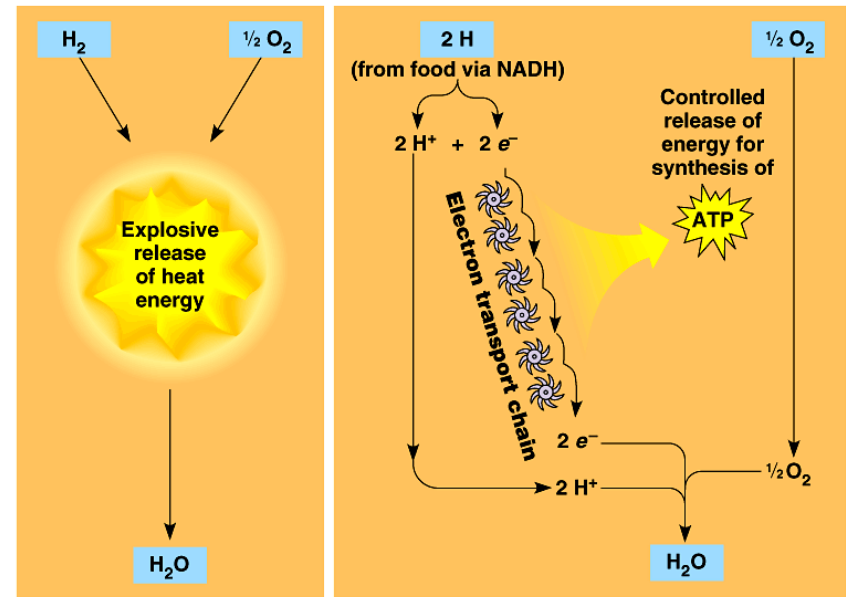
(a) Uncontrolled reaction

(b) Cellular respiration

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# Harvesting of Energy cont.

- Respiration uses an electron transport chain to break the fall of electrons to oxygen into several energy releasing steps not an explosive reaction
- Transport chain consists of mostly protein molecules built into inner mitochondrial membrane
- Electrons from food are shuttled to top of chain by NADH & at bottom oxygen captures the electrons along with hydrogen ions ( $H^+$ ) forming water



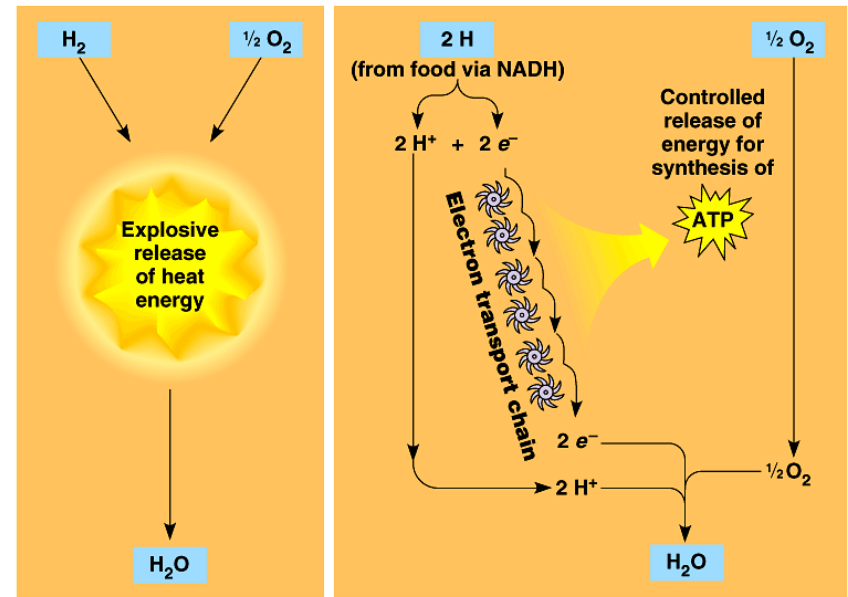
(a) Uncontrolled reaction

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# Harvesting of Energy cont.

- Electron transfer from NADH to oxygen is exergonic reaction with free energy change of -53 kcal/mol but electrons move from 1 carrier molecule to next more electronegative carrier losing small amount of energy with each step until finally reach oxygen which is the most electronegative & is the terminal electron acceptor
- Oxygen 'pulls' the electrons down the chain because it is so electronegative & the energy released in small steps is used to regenerate ATP



(a) Uncontrolled reaction

(b) Cellular respiration

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